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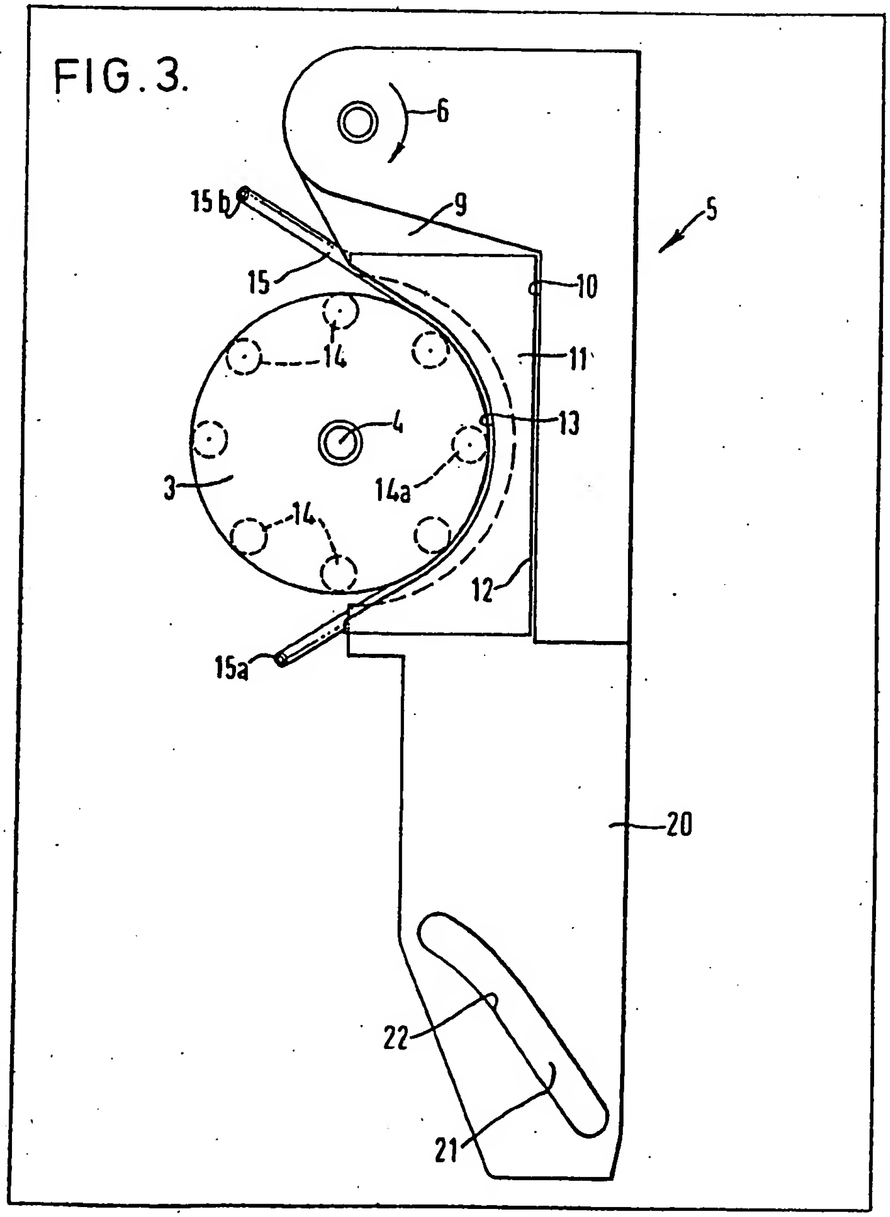
(54) Peristaltic fluid-machines

(57) In a pump a pumping tube 15 is compressed by projections e.g. rollers 14, on a rotor 3 and ~~fixed to a pla~~ten, or "shoe", 11 with an adhesive material. The shoe ~~may be~~ removably mounted on a stator 5 which can be pivoted (as indicated by an arrow 6) by a pin in a cam slot 21 to bring the tube into engagement with the rollers. The rotor may turn in a succession of steps e.g. two-hundred per revolution. There may be a plurality of pumping tubes, shoes and rotors. A jig for mounting the tube on the shoe is described with reference to Figs. 8 and 9 (not shown)

FIG. 3.



Glue

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FIG.1.

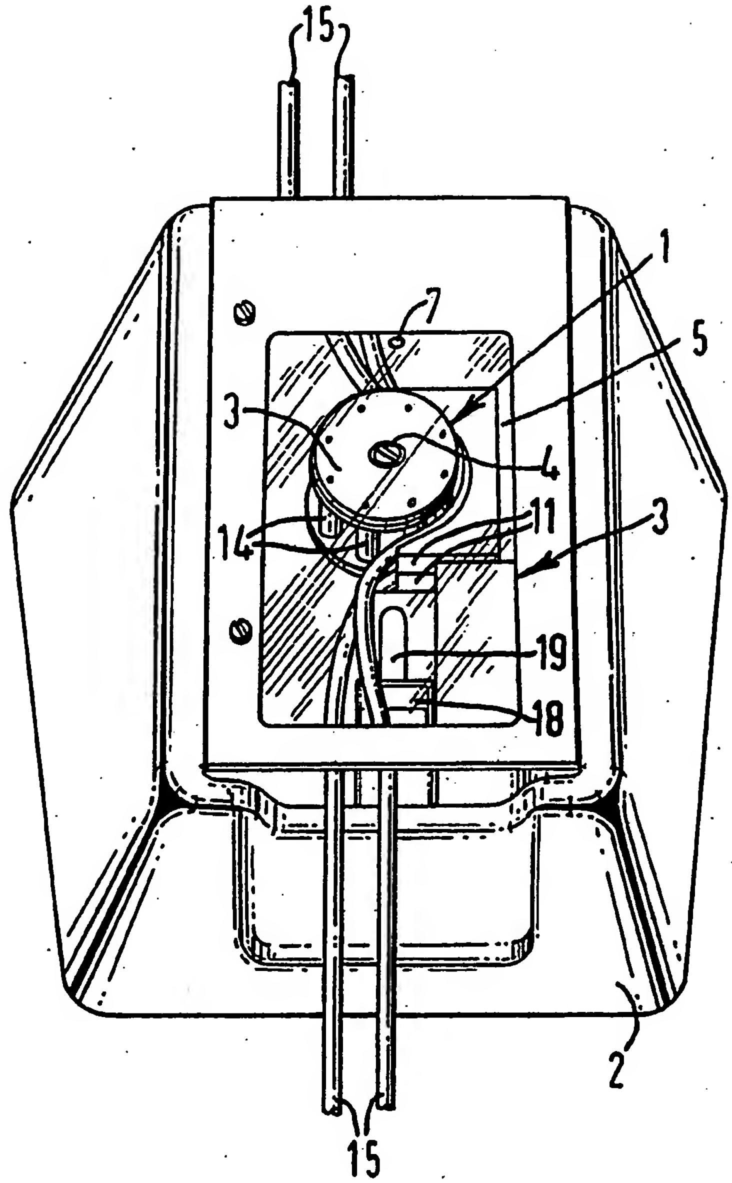
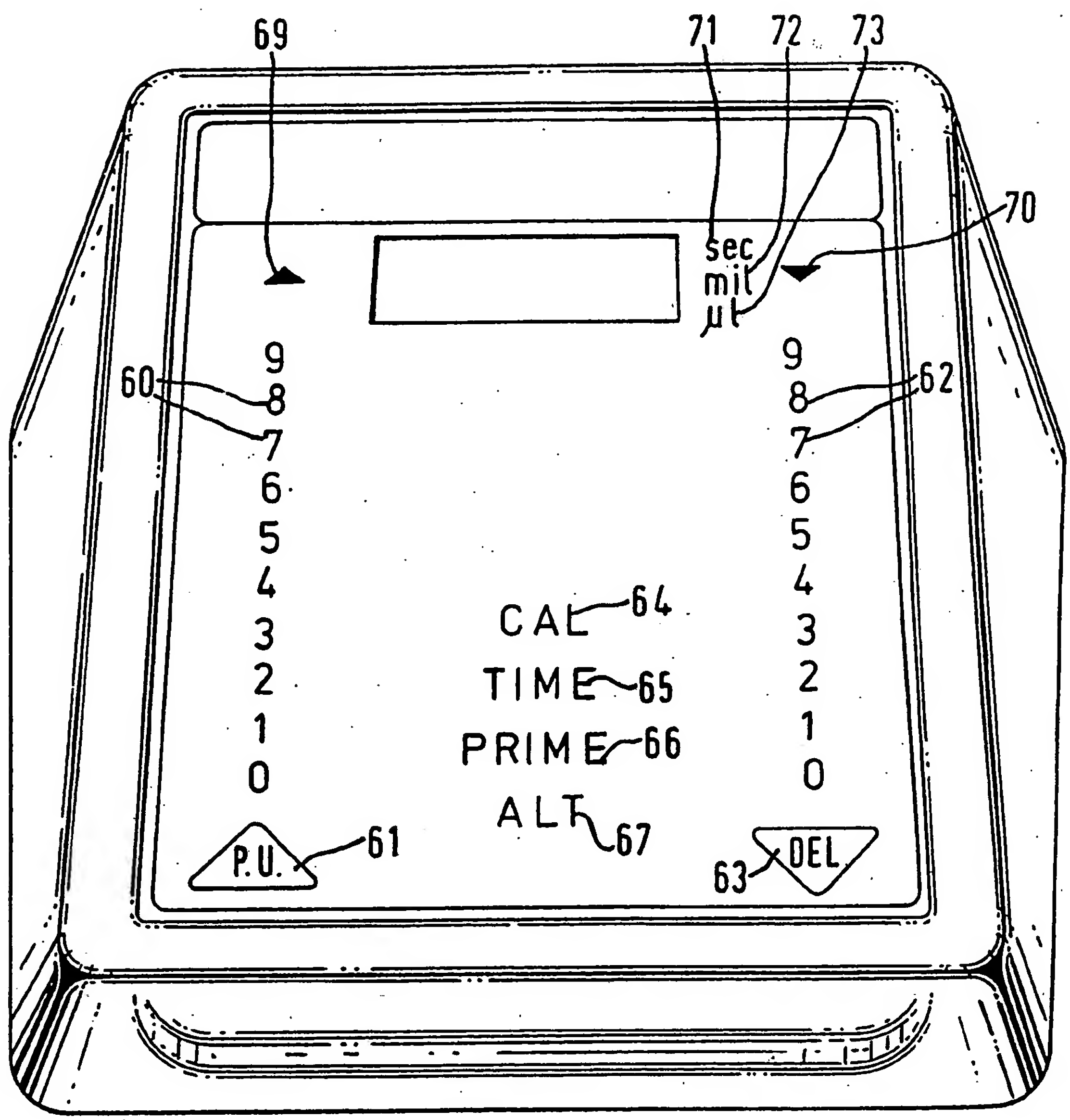


FIG. 2.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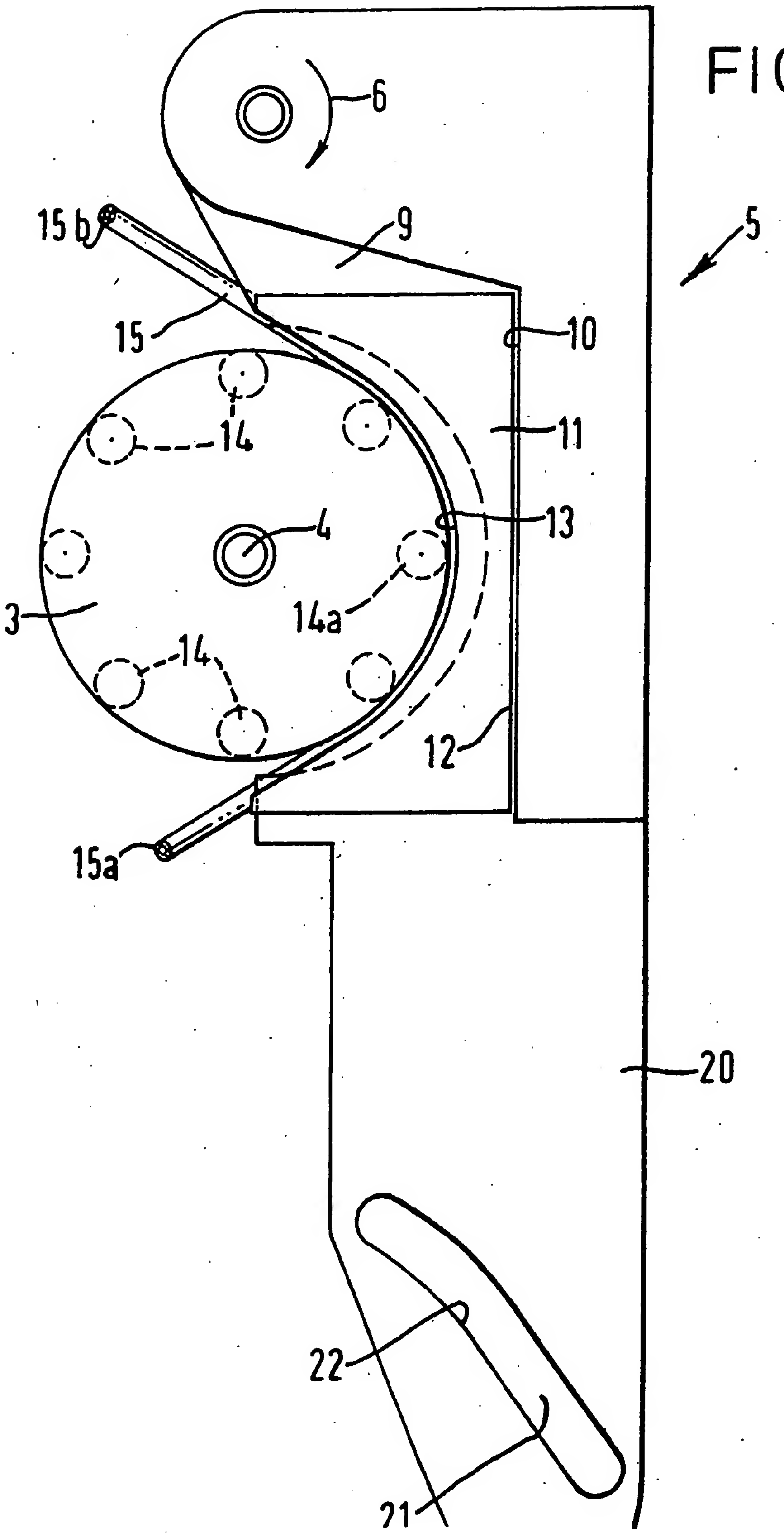

FIG. 3.

FIG. 4.

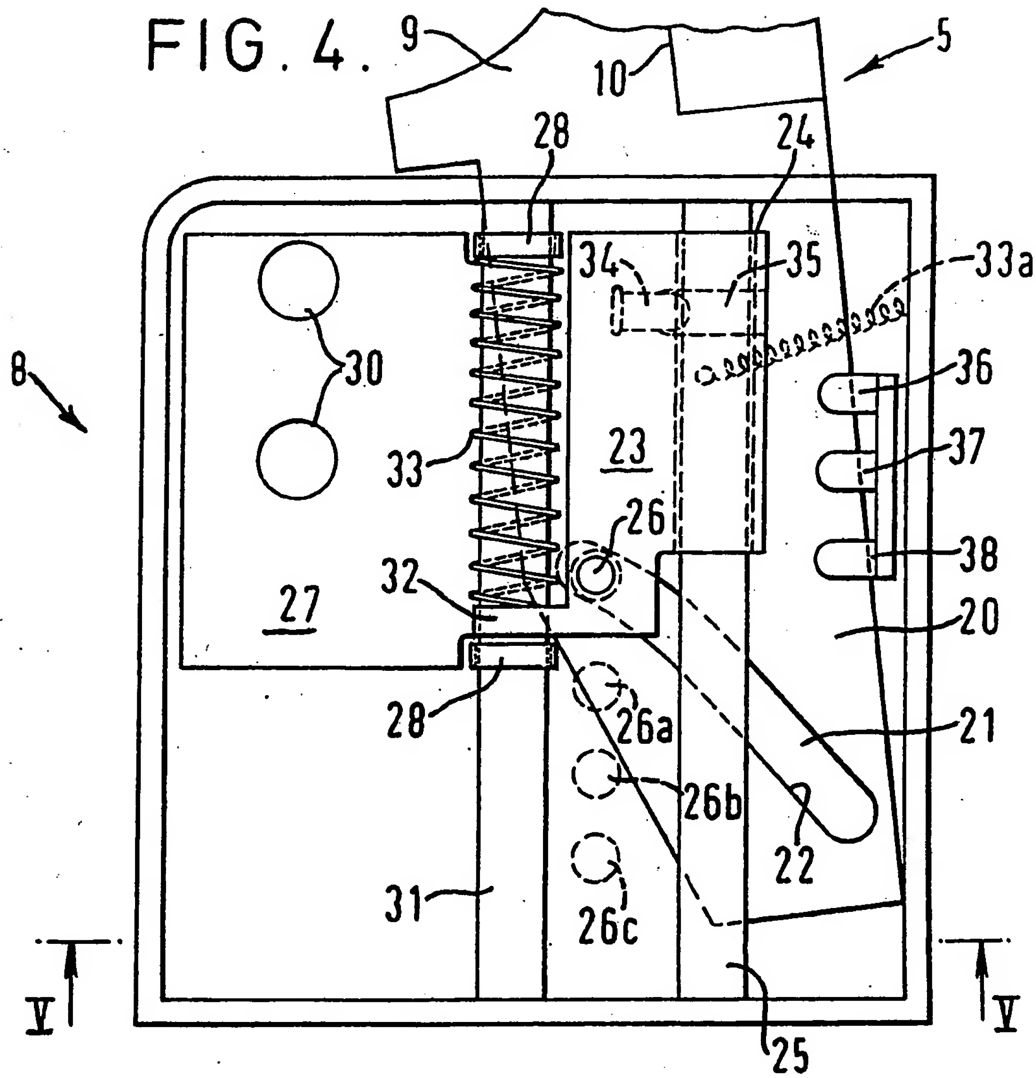
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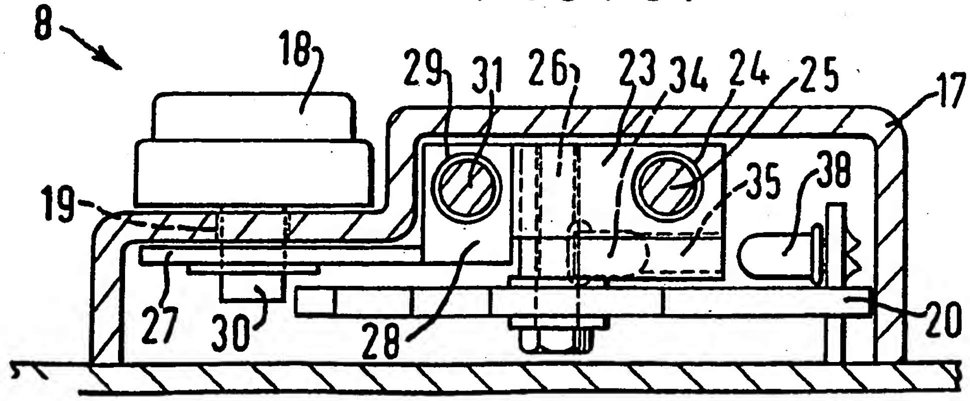
FIG. 5.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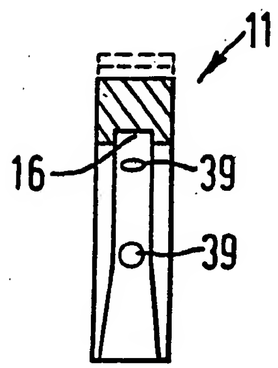


FIG. 7.

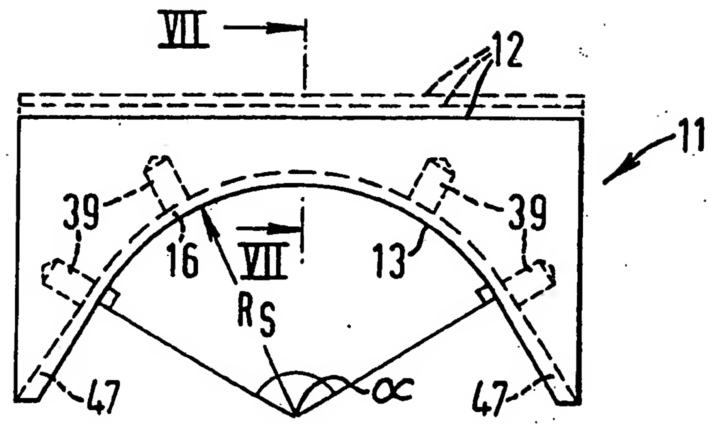


FIG. 6.

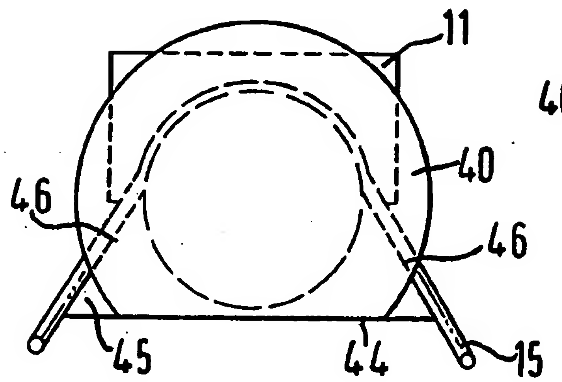


FIG. 9.

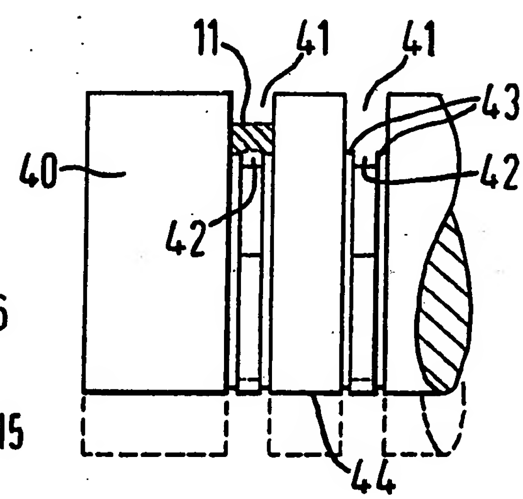
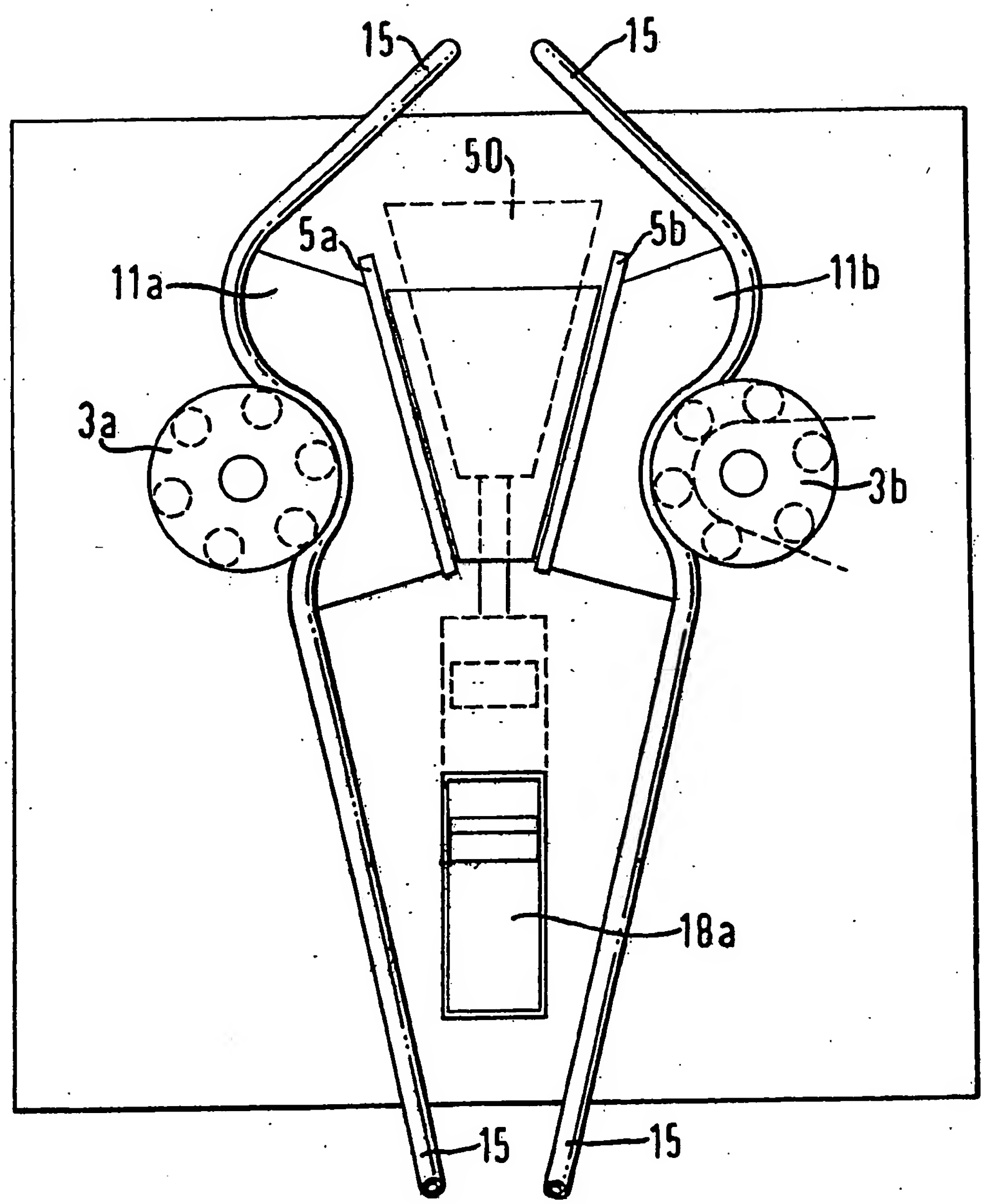


FIG. 8.

FIG. 10.



SPECIFICATION

Peristaltic liquid pickup and/or dispensing means

The invention relates to peristaltic pumps and particularly to liquid pickup and/or dispensing means utilising peristaltic pumps.

In a peristaltic pump, spaced apart rollers are caused to pass in succession over a length of flexible tube, thereby to cause a flow of liquid in the tube in the direction in which the rollers pass over the tube. Thus each roller causes movement along the tube of a small aliquot of liquid and the flexibility of the wall of the tube causes the tube to revert to its original shape, after the roller has passed thereover, to suck liquid forward to fill the tube behind the roller.

Conveniently the rollers are provided at the periphery of a rotor, have their axes extending parallel to the axis of rotation of the rotor and co-operate with a stator which has a portion thereof located closely adjacent the periphery of the rotor such that a flexible tube located between the rotor and said portion of the stator will be flattened by the rollers of the rotor as the rotor rotates, thereby to occlude the bore of the flexible tube and to cause liquid contained in the bore of the tube to move along the tube in the direction in which the rollers of the rotor move with respect to the flexible tube. Preferably the rotor can be driven in either direction of rotation by a reversible electric pulse motor, the number of pulses supplied to the motor following energization thereof being selectable to cause the rotor to effect an angular movement through a desired number of degrees, thereby to cause the pump to pump a desired quantity of liquid through the flexible tube in one direction or the other. Ideally the quantity of fluid pumped is directly proportional to the extent of the angular movement of the rotor.

This ideal situation however does not occur in practice due to manufacturing and settling tolerances and variations in the cross-section of the flexible tube. Thus it is not possible to obtain flexible tube which has a standard accurately constant cross-section over a considerable length and the practice has arisen therefore of using short lengths of standard flexible tube to co-operate with the rotor, such short lengths being joined at their ends to further lengths of tube which lead to vessels from which liquid is picked up by the pump and/or to vessels into which the liquid is discharged by the pump. Joining together the ends of the short lengths of small bore tube to other lengths of tube is a time consuming operation. The portion of the stator which co-operates with the rollers of the rotor to compress the tube therebetween is normally spring mounted and adjustable in position with respect to the remainder of the stator by means of setting screws. Particularly where very small bore tubes are concerned, the operation to set said portion of the stator so as to obtain a precise quantity of fluid pumped not only in one but in both directions for a determined angular movement of the rotor, is again a time consuming operation and the setting may not remain accurate over prolonged use of the pump.

It has also been found necessary to lubricate the external surface of the flexible tube which co-operates with the rollers of the rotor to prevent the tendency of the rollers to drag the tube through the gap between the rotor and the stator. The flexible tube is usually formed of silicone rubber.

Peristaltic pumps have particular though not exclusive application to diagnostic and other tests on human and animal body fluids. Thus the pump can be caused to draw into a tube, which tube already contains a diluent, a precise amount of a sample of body fluid and subsequently to discharge into a vessel from the tube said precise amount of the sample plus a precise amount of the diluent which is thereby mixed with the precise amount of the sample in said vessel. The pickup and discharge step may be repeated many times further to dilute the proportion of the sample in the diluent and precise amounts of other reagents and indicating fluids may be added to the diluted samples to obtain indications, which may be visual or obtained by means of a spectrophotometer, of the nature of the original sample of body fluid.

According to the invention peristaltic liquid pickup and/or dispensing means comprises a peristaltic pump having a stator and a rotor with a plurality of circumferentially spaced projections at its periphery to co-operate with a length of flexible tube and a motor to drive the pump rotor, wherein said length of flexible tube which co-operates with the projections of the rotor of the pump is located in position to secure it against longitudinal movement by adhering it to a member locatable with respect to the stator of the pump.

Advantageously the motor is an electric motor and control means are provided to control the extent of angular rotation of the rotor of the pump upon energization of the electric motor.

Preferably said member comprises a shoe having a concave arcuate face with a groove extending along the arcuate face, a portion of the periphery of said length of flexible tube extending into the groove and being secured therein by adhesive and the shoe being so located with respect to the stator of the pump that a further portion of the periphery of said length of flexible tube, diametrically opposite said portion, is acted upon by the rotor in operation of the pump. Another face of the shoe co-operates with a face of the stator of the pump precisely to locate the shoe with respect to the stator. Said another face of the shoe is preferably a face extending parallel to a tangent to a mid-point of said arcuate face of the shoe and the shoe is so located with respect to the stator that it can float slightly with respect to the stator in directions parallel to said another face. Thus the tube wrapped around the concave arcuate face of the shoe centres itself with respect to the rotor.

A plurality of said shoes may be locatable together in the stator or the shoe may be a

multiple shoe with a plurality of parallel grooves extending along the arcuate face to receive a plurality of parallel lengths of tube acted upon simultaneously by the rotor upon operation of the pump. Such a plurality of shoes or multiple shoe can comprise a cartridge unit insertable into a pump and readily removable therefrom to allow a similar unit to be inserted into the pump. The stator may be pivotally mounted about an axis parallel to the axis of the rotor to allow the stator to be pivoted away from the rotor for insertion of the shoe or shoes.

Latch means are preferably provided for the stator and include resilient means biassing the stator in a direction to cause the length of tube or lengths of tubes to be pressed into engagement with the rotor. The latch means preferably comprise a latch pin engaged in a slot in the stator and mounted on a slide such that movement of the slide causes the pin to move longitudinally of the slot and to bear against one side wall of the slot thereby to cam the stator towards the rotor. Advantageously the slide is movable by a further slide which is movable beyond positions at which in operation the slide will be stopped by engagement of the tube or tubes with the rotor. Continued movement of the further slide to a latched position after the slide has been stopped at one of said positions preferably causes compression of a spring which forms said resilient means biassing the stator towards the rotor. Thus the position at which the slide is stopped will, for shoes of the same size, depend upon the diameter of the tube adhered to the shoe. Sensing means may be provided to indicate the position at which the slide stops thereby to give an indication of the size of tube being employed.

The pump may if desired have two rotors and a pair of shoes may be insertable in the pump, for example back to back, for simultaneous multiple operation, packing means preferably being insertable between the pair of shoes precisely to locate them.

The control means to control the extent of angular rotation of the rotor of the pump upon energization of the electric motor preferably includes compensation means for self-calibration. In operation a nominal number of steps of the electric motor for a desired discharge of liquid from one or other end of the flexible tube can be effected and the actual discharge accurately measured, preferably by weighing the discharge, the measured amount then being fed back into the control means to obtain a multiplication factor by which said nominal number of steps will be multiplied by the control means in subsequent operations thereby to obtain the desired discharge in such subsequent operations. Thus the discharge is proportional to the number of stepping pulses supplied to the electric motor and the pump itself is precise rather than accurate, accuracy being obtained by way of the control means rather than by mechanical setting. Where a shoe has a plurality of flexible tubes secured thereto or a plurality of shoes are used simultaneously, the control means can include a separate channel for each of the flexible tubes, each channel including the compensation means for self-calibration.

Since the or each tube is secured against longitudinal movement by adhering it to a respective shoe, lubrication of the outer surface of the flexible tube is not required.

The shoe to have the tube or tubes secured thereto can be formed of a relatively cheap moulded plastics material, such as ABS or an acrylic, so that it can be "disposable" that is to say it can be thrown away when the tube or tubes become worn or the material of the tube or tubes thereof ages so that the calibration is no longer accurate. If desired, the calibration can be effected using a standard colour indicator and a spectrophotometer, the colour density of a sample after successive dilutions of liquid pumped by the apparatus giving an error reading to be fed back to the compensation means of the control means for self-calibration.

The invention is diagrammatically illustrated by way of example in the accompanying drawings, in which:—

Figure 1 shows a peristaltic pump of liquid pickup and/or dispensing means according to the invention;

Figure 2 shows a control console for liquid pickup and/or dispensing means according to the invention;

Figure 3 shows a rotor and stator of the pump of Figure 1;

Figure 4 is a plan view, after removal of a cover, of stator locking means of the pump of Figures 1 and 3;

Figure 5 is a sectional elevation taken on line V—V of Figure 4;

Figure 6 is a plan view of a tubing shoe for use in the pump of Figure 1;

Figure 7 is a sectional view taken on line VII—VII of Figure 6;

Figure 8 shows a tool for facilitating adhesion of flexible tubes to shoes to be engaged in the stator of peristaltic pumps;

Figure 9 is an end view corresponding to Figure 8; and

Figure 10 is a plan of a twin rotor peristaltic pump of liquid pickup and/or dispensing means according to the invention.

Referring to the drawings, a peristaltic pump 1 is mounted on a raised base 2 and comprises a rotor 3 having a vertical axis of rotation 4 and a stator 5 which is pivotable in the direction indicated by the arrow 6 about a pivot 7 and in the pivoted position shown is latchable by a latch 8. An electrical stepping motor (not shown) is mounted in the raised base 2 and has an output shaft coupled to the rotor 3 to rotate the rotor 3 about the axis 4. The stepping motor may, for example, require 200 pulses of electrical energy to cause it to effect one complete revolution of the rotor 3.

The stator 5 has a support shelf 9 defining, with a reference face 10, a recess within which a shoe 11 is received. The shoe 11 has a side wall 12 to

co-operate with the reference face 10. Opposite the side wall 12 the shoe 11 has a concave, arcuate edge face 13. A plurality of rollers 14, as shown eight rollers 14, are mounted circumferentially spaced around the periphery of the rotor 3 and each roller is freely rotatable about an axis parallel to the axis 4 of the rotor 3. With the stator 5 in the position shown the gap between the outer periphery of the roller 14*a* at the righthand side of the rotor 3 and the arcuate edge 13 of the shoe 11 is smaller than the outside diameter of a flexible tube 15. The tube 15 is secured by adhesive in a groove in the arcuate edge 13 of the shoe 11, the shoe 11 being so proportioned that a roller 14 in the position of the roller 14*a* will compress the tube 15 sufficiently to occlude the bore thereof without crushing the material of the wall of the tube. If the rotor 3 is rotated in a clockwise direction as viewed in Figures 1 and 3, liquid contained within the tube 15 will be discharged from an end 15*a* of the tube 15 by the successive action of the rollers 14 and conversely if the rotor 3 is rotated in an anticlockwise direction then fluid will be discharged from an end 15*b* of the tube 15.

Figures 6 and 7 show the shoe 11 in more detail and show that the edge 13 has a radius Rs over an arc subtended by an angle α of 120°, radius lines from the axis 4 of the rotor 3 meeting the edge face 13 at right angles at the ends of the arc, the radius of the rotor being Rr and Rr and Rs having the relationship Rs = Rr + (<Tw × 2) where Tw equals the wall thickness of the tube 15. Securing the tube 15 in a shallow groove 16 in the arcuate edge face 13 prevents the tube 15 being drawn through the gap between the rotor 3 and the stator 5 by the action of the rollers 14 thereon and avoids the need for lubrication of the outer surface of the tube 15.

A plurality of the shoes 11 each mounting a respective tube 15 may be supported on the shelf 9 of the stator 5 with the side wall 12 of each shoe engaged with the reference face 10 of the stator 5. Figure 1 show two shoes 11 each with a respective tube 15.

The latch 8 is shown in greater detail in Figures 4 and 5. A cover 17 protects most of the latch from liquid which might be spilled if a tube 15 should burst. Only a slider 18, communicating with the remainder of the latch 8 through a slot 19, projects above the cover 17. A lower end portion 20 of the stator 5 projects into the cover 17 through a slot in the cover. A slot 21 is provided in the portion 20 of the stator 5, the slot 21 defining a cam face 22.

A slide 23 has a bore 24 whereby it is slidable on a first fixed rod 25 and mounts a cam pin 26 engaged in the slot 21. It will be seen that movement of the slide 23 along the rod 24 from the position of Figure 4 will, due to the cam pin 25 bearing on the cam face 22, pivot the stator 5 clockwise about the axis 7 to engage the tube or tubes 15 of a shoe or shoes 11 supported on the shelf 9 of the stator with the rollers 14 of the rotor 3. The slide 23 is not moved directly but rather by a further slide 27 which has two ears 28 with circular bores 29 therein. the further slide 27 is coupled to the slider 18 by two pins 30 which project through the slot 19 in the cover 17. The further slide 27 is mounted to slide on a further fixed rod 31 by means of the ears 28 and the slider 18 when slid fully downardly to the position of Figure 1 is automatically latched in that position by engaging a latch pin (not shown). The slide 23 has a projection 32 with a bore therein engaged on the further fixed rod 31. A compression spring 33 extends between the projection 32 and the upper ear 28.

When the slider 18 is slid downwardly, *i.e.* away from the rotor 3, the spring 33 entrains the slide 23 for movement with the further slide 27. When the tube or tubes 15 of the shoe or shoes 11 on the stator 5 abut the rollers 14 on the rotor 3, the slide 23 is stopped but the further slide 27 continues to its latching position, thereby compressing the spring 33 so that the tubes are held pressed against the rotor 3 by the compressed force of the spring 33.

A return spring 33*a* preferably pulls the stator 5 away from the rotor 3 when the latch on the slider 18 is released, thereby allowing removal of the shoes 11 and tubes 15.

Figures 6 and 7 show that the shoes 11 can be any one of three sizes, the dimension which varies being the distance between the arcuate face 13 and the side face 12 which abuts the reference face 10 of the stator. Three different diameters of tubes 15 are used with the three sizes of shoes 11, the larger diameter tubes going with the larger shoes.

A sensor is provided to indicate to the control console shown in Figure 2, the size of tube 15 being used. Referring to Figures 4 and 5 the sensor comprises an infra red source 34 mounted in a bore 35 in the slide 23 and three infra red sensors 36, 37, 38 mounted in a row in positions where they can be energized by the infra red source 34 to give an indication. If a larger size tube and shoe are being used when the slide 23 will only be moved to a position in which the cam pin 26 is at a position indicated at 26*a* in Figure 4 and the infra red sensor 36 will be energized. If a medium size tube and shoe are being used, the cam pin 26 will move to a position 26*b* and the sensor 37 will be energized and if a small size tube and shoe are being used, the cam pin 26 will move to a position 26*c* and the sensor 38 will be energized. It will be seen that in the position 26*a*, the spring 33, when the slider 18 reaches its latched position, will be compressed very much more than it will be if the cam pin 26 had moved to the position 26*c*. Thus for larger tubes there is a higher spring loading of them against the rotor than there is for smaller sized tubes. In addition to the sensing and the indication to the control console provided by the sensors 36, 37, 38, the shoes will preferably be colour coded to ensure that where a plurality of shoes and tubes are used together, they are all of the same kind, that is to say there is not one large tube and one small tube.

Referring to Figures 6 and 7, it will be seen that bores 39 are provided in the base of the groove 16 to provide additional keying for the adhesive used to secure the tube 15 in the groove 16.

Figures 8 and 9 show jigs used to ensure correct location of the tubes 15 in the grooves 16. A member 40 which initially was of circular section has grooves 41 turned thereinto, the grooves 41 having a deeper central portion 42 thereby to form shoulders 43. A portion indicated in dotted lines is milled off from one side of the member 40 thereby to form a flat surface 44 on which the member 40 can stand. Generally triangular shaped members 45 with a thickness such that they can be pressed into the lower parts of the grooves 41 and having a generally semi-circular recess in their upper face are provided such that when shoes 11, having had adhesive applied thereto within the groove 16 and a tube adhered to the adhesive, are laid in the position indicated by the dotted lines at the upper part of Figure 9, the angled side edges 46 of the members 45 press the tube firmly into tangential lead outs 47 provided at the ends of the arcuate face 13 of the shoes 11 thereby ensuring that the tubes 15 are pressed firmly into the lead out portions 47 of the shoes 11. Although not shown in the drawing, a similar but slightly smaller flat to the flat 44 could be provided at the upper part of the member 40 such that the side face 12 of the shoes projected slightly therefrom, a weight or top plate then being applied to the side faces 12 of the shoes 11 to retain them in position. This can form the tubes 15 adhered to the shoes 11 to an oval form which is desirable since the tubes tend to move to an oval form after a short period of use and thus in the past have been given a run-in period to cause the ovality before they were used for precise measuring. With the tubes formed in the jigs to an oval form the run-in period can be considerably reduced.

Figure 10 shows that a peristaltic pump can have twin rotors 3*a* and 3*b* each co-operating with a plurality, for example six, shoes 11*a*, 11*b* with a single slider 18*a* similar to the slider shown in Figure 1 coupled to a frusto-conical member 50 which locates a pair of stators 5*a*, 5*b* and causes them to be pressed resiliently outwardly to engage the tubes 15 with the rotors 3*a* and 3*b*.

Referring to Figure 2, a console is provided with touch sensitive keys for control. The lefthand side of the board has pickup keys 60 indicated 0 to 9 on which a volume to be picked up can be set and when the volume has been set, a pickup key 61 is operated to cause operation of the pump 1. Likewise the righthand side of the board has delivery keys 62 marked 0 to 9 and a delivery operate key 63. Further keys comprise a calibrate key 64 for electronic calibration of the pump, a time key 65 to allow a time setting to be made, a prime key 66 to be used to fill tubes prior to metering operations and an alternate key 67 which allows alternate pickup and delivery. A liquid crystal display 68 shows the volumes or times entered using the keys 61, 62 and 65, a pickup indicator 69 indicates when the pump is ready to pickup and a delivery indicator 70 indicates when the pump is ready to deliver. A seconds indicator 71 is illuminated when time intervals are entered, a millilitre indicator 72 is automatically illuminated when large tubes are inserted into the pump unit and a microlitre indicator is automatically illuminated when mid-range or small tubes are inserted into the pump unit.

Preferably the motor which drives the rotor 3 of the pump 1 is a four-phase 200 steps per revolution motor which can give positive operation and very high accuracy. It is suggested that small size tubes should be used for the 5 μ litre to 500 μ litre range, middle size tubes in the 20 μ litre to 2000 μ litre range and large tubes in the 50 μ litre range and above. The tubes are of silicone rubber and where different sized tubes are to be used then a separate jig, of the kind shown in Figures 8 and 9, is required for each size, the main difference between the sizes being the width of the grooves 42 and shoulders 43 in the grooves 41, the grooves 42 becoming wider and the shoulders 43 narrower as the size of tube increases.

The control console of Figure 2 can be provided adjacent the peristaltic pump 1 or can be remote therefrom, remote control being desirable where the liquids being pumped are toxic, bacteriological or radioactive for example.

For calibration a standard volume (*e.g.* 1 millilitre) will be dispensed and measured (gravimetrically or radioactively). If the volume dispensed is inaccurate, say 985 μ litres *i.e.* low by 15 μ litres, the calibrate key 64 is touched followed by keys 985 of the keyboard array 62. This information is thus entered into a micro-processor unit of the control means as a correction factor. The MPU memory will store the correction factor for the standard volume and apply it to any volume selected in the deliver mode. Since the floating shoe causes equal dispensing and pickup, the correction factor also applies in the pickup mode.

The time key 65 allows a time mode to be set so that the keyboards will give time in seconds and tenths of a second. A time interval may, therefore, be programmed in prior to making each delivery. A separate time interval may also be programmed in to give an interval before each volume to be picked up.

CLAIMS

1. Peristaltic liquid pickup and/or dispensing means comprising a peristaltic pump having a stator and a rotor with a plurality of circumferentially spaced projections at its periphery to co-operate with a length of flexible tube and a motor to drive the pump rotor, wherein said length of flexible tube which co-operates with the projections of the rotor of the pump is located in position to secure it against longitudinal movement by adhering it to a member locatable with respect to the stator of the pump.

2. Peristaltic liquid pickup and/or dispensing means according to claim 1, wherein the motor is an electric motor and control means are provided to control the extent of angular rotation of the rotor of the pump upon energization of the electric motor.

3. Peristaltic liquid pickup and/or dispensing means according to claim 1 or claim 2, wherein said member comprises a shoe having a concave arcuate face with a groove extending along the arcuate face, a portion of the periphery of said length of flexible tube extending into the groove and being secured therein by adhesive and the shoe being so located with respect to the stator of the pump that a further portion of the periphery of said length of flexible tube, diametrically opposite said portion, is acted upon by the rotor in operation of the pump.

4. Peristaltic liquid pickup and/or dispensing means according to claim 3, in which another face of the shoe co-operates with a face of the stator of the pump precisely to locate the shoe with respect to the stator.

5. Peristaltic liquid pickup and/or dispensing means according to claim 4, in which said another face of the shoe is a face extending parallel to a tangent to a mid-point of said arcuate face of the shoe and the shoe is so located with respect to the stator that it can float slightly with respect to the stator in directions parallel to said another face.

6. Peristaltic liquid pickup and/or dispensing means according to any one of claims 2 to 5, in which a plurality of said shoes are located together in the stator or the shoe is a multiple shoe with a plurality of parallel grooves extending along the arcuate face to receive a plurality of parallel lengths of tube acted upon simultaneously by the rotor upon operation of the pump.

7. Peristaltic liquid pickup and/or dispensing means according to any one of the preceding claims, in which the stator is pivotally mounted about an axis parallel to the axis of the rotor to allow the stator to be pivoted away from the rotor for insertion of the shoe.

8. Peristaltic liquid pickup and/or dispensing means according to claim 7, including latch means for the stator, said latch means including resilient means biassing the stator in a direction to cause the length of tube to be pressed into engagement with the rotor.

9. Peristaltic liquid pickup and/or dispensing means according to claim 8, in which the latch means comprise a latch pin engaged in a slot in the stator and mounted on a slide such that movement of the slide causes the pin to move longitudinally of the slot and to bear against one side wall of the slot thereby to cam the stator towards the rotor.

10. Peristaltic liquid pickup and/or dispensing means according to claim 9, in which the slide is movable by a further slide which is movable beyond positions at which in operation the slide will be stopped by engagement of the tube or tubes with the rotor.

11. Peristaltic liquid pickup and/or dispensing means according to claim 10, in which continued movement of the further slide to a latched position after the slide has been stopped at one of said positions causes compression of a spring which forms said resilient means biassing the stator towards the rotor.

12. Peristaltic liquid pickup and/or dispensing means including sensing means to indicate the position at which the slide stops thereby to give an indication of the size of tube being employed.

13. Peristaltic liquid pickup and/or dispensing means according to any one of the preceding claims, wherein the pump has two rotors and a pair of shoes can be inserted in the pump back to back for simultaneous multiple operation, packing means being insertable between the pair of shoes precisely to locate them.

14. Peristaltic liquid pickup and/or dispensing means according to claim 2 or any one of claims 3 to 13 when appendant to claim 2, wherein the control means to control the extent of angular rotation of the rotor of the pump upon energization of the electric motor includes compensation means for self-calibration.

15. Peristaltic liquid pickup and/or dispensing means according to claim 2 or any one of claims 3 to 14 when appendant to claim 2, in which the shoe is formed of a relatively cheap moulded plastics material.

16. Peristaltic liquid pickup and/or dispensing means substantially as hereinbefore described and illustrated with reference to the accompanying drawings.

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